

**TOXICOLOGICAL PROFILE FOR
WHITE PHOSPHORUS**

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1. PUBLIC HEALTH STATEMENT

potential sources of exposure to people. However, because white phosphorus reacts very quickly with oxygen in the air, it may not be found far away from sources of contamination.

The fate of white phosphorus smoke is similar to the fate of reaction products of white phosphorus vapor in air. White phosphorus vapor in air reacts with oxygen and is changed to relatively harmless chemicals within minutes. However, particles in the air may have a protective coating that makes them unreactive for a longer time. White phosphorus reacts mainly with oxygen in water and may stay in water for hours to days. However, chunks of white phosphorus coated with protective layers may stay in water and soil for years if oxygen levels in the water and soil are very low.

In water with low oxygen, white phosphorus may react with water to form a compound called phosphine. Phosphine is a highly toxic gas and quickly moves from water to air. Phosphine in air is changed to less harmful chemicals in less than a day. In water, white phosphorus builds up slightly in the bodies of fish. The other chemicals in white phosphorus smoke are mainly changed to relatively harmless chemicals in water and soil. White phosphorus may stay in soil for a few days before it is changed to less harmful chemicals. However, in deeper soil and the bottom deposits of rivers and lakes where there is no oxygen, white phosphorus may remain for several thousand years. White phosphorus binds moderately to soil and typically doesn't move deep in soil with oxygen-depleted rainwater.

Chapter 5 provides more information about the fate and movement of white phosphorus in the environment.

1.3 HOW MIGHT I BE EXPOSED TO WHITE PHOSPHORUS AND WHITE PHOSPHORUS SMOKE?

You may be exposed to white phosphorus by breathing in air that contains white phosphorus or by swallowing water or food contaminated with it. White phosphorus has rarely been found in air. Therefore, unless you are near military facilities during training exercises that use white phosphorus ammunition, exposure to it by breathing air will be insignificant. White phosphorus

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has not been found in drinking water or any food other than fish caught in contaminated water and game birds from contaminated areas. The maximum level found was 207 milligrams of white phosphorus per kilogram (207 mg/kg) in the muscle of channel catfish caught from the Yellow Lake in Pine Bluff, Arkansas. Some people are exposed to low levels of white phosphorus by eating contaminated food. People who work in industries that produce or use white phosphorus, people who eat contaminated fish or game birds, and people who live near phosphorus-containing waste sites may be exposed to white phosphorus at higher levels than the rest of the population. Other than exposure of certain workers at the Pine Bluff Arsenal in Arkansas, very few studies exist that have information on exposure to high levels of white phosphorus.

Most known cases of fatal or severe exposure to white phosphorus resulted from adults or children accidentally or deliberately swallowing rat poisons or fireworks or handling munitions containing white phosphorus. Other known instances of severe exposure of workers were a result of accidents in white phosphorus loading plants. People, particularly those in the military who use phosphorus-containing ammunitions, may be exposed to white phosphorus smoke during warfare, training exercises, and accidents.

1.4 HOW CAN WHITE PHOSPHORUS AND WHITE PHOSPHORUS SMOKE ENTER AND LEAVE MY BODY?

White phosphorus can enter your body when you breathe air containing white phosphorus. We do not know if white phosphorus in your lungs will enter the blood. White phosphorus can also enter your body when you eat food or drink water containing white phosphorus or when you are burned by it. We do not know if white phosphorus can enter your body through skin that has not been cut or burned. If it enters your body when you eat, drink, or are burned, white phosphorus enters the blood rapidly. We do not know if it changes into other compounds in the blood. Most of the white phosphorus that enters your body leaves in urine and feces after several days. White phosphorus smoke can enter your lungs when you breathe air containing it. When that happens, we do not know if it will enter your blood or how it will leave your body. For more information, please read Chapter 2.

3. CHEMICAL AND PHYSICAL INFORMATION

3.1 CHEMICAL IDENTITY

Information regarding the chemical identity of white phosphorus is located in Table 3-1.

3.2 PHYSICAL AND CHEMICAL PROPERTIES

Information regarding the physical and chemical properties of white phosphorus and white phosphorus smoke is located in Table 3-2.

Elemental phosphorus exists in several allotropic forms (Van Wazer 1982). The best known and most important commercially is the a-white phosphorus whose properties are given in Table 3-2. Commercial white phosphorus is 99.9% pure, with a slight yellow color caused by traces of red phosphorus impurities. Hence, white phosphorus also is known as yellow phosphorus. When a-white phosphorus is cooled below -79.6°C , P-white phosphorus forms. Other important solid allotropes of phosphorus are red and black phosphorus (Van Wazer 1982).

The U.S. Army uses at least two phosphorus-based smoke/obscurants for training and testing activities (Shinn et al. 1985). One such agent is white phosphorus/felt (WP/F), and the other is red phosphorus/butyl rubber (Spanggord et al. 1985). WP/F consists of 75-80% white phosphorus solidified into a cellulose (felt) matrix (20-25%). When WP/F is burnt, besides unburnt white phosphorus, the smoke consists primarily of oxidation and hydrolysis products of phosphorus. For example, when white phosphorus burns in air it produces oxides of phosphorus including phosphorus pentoxide (P_4O_{10}), and phosphorus trioxide (P_4O_6). These oxides react with moisture present in air to form a number of phosphorus-containing acids, such as orthophosphoric acid (H_3PO_4), pyrophosphoric acid ($\text{H}_4\text{P}_2\text{O}_7$), orthophosphorus acid (H_3PO_3), hypophosphorus acid (H_3PO_2), polyphosphoric acid of the general formula $\text{H}_{n+2}\text{P}_n\text{O}_{3n+1}$, where $n=2-8$, and a homologous series of linear and cyclic P_6 - P_{16} polyphosphates (Spanggord et al. 1983; Tolle et al. 1988). The composition of white phosphorus smoke will change with time (Spanggord et al. 1988). In the absence of stoichiometric quantities of oxygen, phosphine (PH_3) may form in WP/F smoke from the reaction of unreacted phosphorus with moisture in air (Spanggord et al. 1983).

4. PRODUCTION, IMPORT, USE, AND DISPOSAL

4.3 USE

In 1991, $\approx 83\%$ of elemental phosphorus available in the nonmilitary market was used in the production of phosphoric acid and phosphates, 12% was used in the production of direct reaction chemicals, such as phosphorus trichloride, pentasulfide, and pentoxide and red phosphorus, and 5% was exported (CMR 1991; EPA 1989). Phosphates are generally used in the fertilizer industry, food and beverage industry, industrial and institution cleaning compounds, water and waste treatment, animal diets and in metal treatment (CMR 1991; van Wazer 1982). Small amounts of white phosphorus are used in roach and rodent poisons (van Wazer 1982). In military use, white phosphorus is used as an ammunition for mortar and artillery shells and hand and rifle grenades (EPA 1989). In the past, white phosphorus was used in the manufacture of matches. However, due to health considerations (jaw-bone necrosis), red phosphorus and tetraphosphorus trisulfide (P_4S_3) have replaced white phosphorus since the Beme Convention of 1906 (Nyunt 1983). More recently, the use of white phosphorus has been suggested for removing nitric oxide from flue gas generated during the combustion of fossil fuels in power plants (Chang and Lee 1992; Chang and Liu 1990; Liu et al. 1991).

4.4 DISPOSAL

According to the United Nation's treatment and disposal methods for wastes containing phosphorus, the two recommended methods of disposal are incineration and open burning (HSDB 1993). In the open burning method, the waste should be mixed with wet earth, allowed to dry, and ignited in a remote place. The ultimate method of disposal is controlled incineration and treatment of emitted gases by alkaline scrubbing and particle removal equipment (HSDB 1993). Landfilling phosphorus-containing wastes is not recommended by the United Nation's treatment and disposal methods (HSDB 1993). However, most of the wastes produced by U.S. manufacturers or processors of white phosphorus are disposed of in landfills (see Section 52.3). In the current disposal practice, retired or outdated army munitions are reprocessed to recover phosphorus. The munitions shells, which are still contaminated with white phosphorus, are incinerated in fluidized bed incinerators equipped with after burners and scrubbers (Berkowitz et al. 1981; Uhrmacher et al. 1985). Waste water containing phosphorus (phossy water) can be treated with ozone in a sparged stirred reactor (Campbell 1977). The resulting phosphate ions may be removed as a calcium phosphate precipitate by adding lime. Campbell (1977) claimed this process reduced the phosphorus levels in phossy water below the limit of detection ($<22 \mu\text{g/L}$).